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Pesticide Residues and Vertical Integration in Florida Strawberries and Tomatoes

by

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Abstract

Government regulations and increased consumer concern about pesticide residues in food increase the potential costs to producers and processors associated with food safety risks. Vertical coordination is an economic response for mitigating the costs associated with uncertain pesticide residue levels. Data from a survey of Florida strawberry and tomato growers were used to test the hypothesis that vertical integration is associated with a lower mean and variance of pesticide residues. The results confirm a significant negative relationship between vertical integration and the mean and variance of insecticide residues in Florida strawberries and tomatoes.

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Introduction

Since the late 1980s, awareness of the possible negative health effects that can result from consumption of pesticide residues through food has spurred increasing concern about pesticide use and food handling by agricultural producers and processors (Roberts *et al.*; Sachs, Blair and Richter). Concerns about residues occurring in fruits and vegetables are especially high as increased consumption of these products is being encouraged for nutritional reasons (Eom; Stevens and Kilmer). Consumer preference for safer food is reflected in the growing demand for pesticide-free products (Eom; Lynch; Misra, Huang and Ott). The increase in consumer concern has prompted the Environmental Protection Agency (EPA), the Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA) to review and refine residue tolerance standards and to improve the monitoring and enforcement of these standards (USDA; USDA/AMS). A critical component of these efforts is increased research on the factors that affect pesticide residue levels.

The government regulations and increased consumer concern about pesticide residues in food can increase the potential costs associated with food safety risks. However, they also create opportunities for cost savings through improved risk management and for increased profitability through product differentiation based on safer food products (Caswell, Roberts and Jordan Lin; Roberts *et al.*). A number of recent studies have pointed out that the objectives of reducing the risks associated with food

safety and of meeting consumer demand for specific food attributes create incentives for vertical coordination and integration (Caswell, Roberts and Jordan Lin; Hennessy; Roberts *et al*). This is particularly true in the case of pesticide residues where control of pesticide applications at the producer level is critical to the safety of the final product. In addition, the imperfect information available to processors and marketers is exacerbated by the low accuracy of current technology for testing product safety (Caswell, Roberts and Jordan Lin; Hennessy; Roberts *et al*).

The intent of this article is to quantitatively investigate the relationship between vertical integration and pesticide residues. Drawing from the general theory of firm-level decision-making under risk, it is hypothesized that vertical integration is an economic response for mitigating the costs associated with uncertain pesticide residue levels. A significant negative relationship between vertical integration and pesticide residue levels and variability may point to an important market-based incentive for residue reduction. This could also suggest new targets for government policies promoting food safety. Data from a survey of Florida strawberry and tomato growers are used to test for a relationship between vertical integration and the mean and variance of pesticide residue levels.

Understanding Vertical Integration

Vertical integration is at the higher end of a spectrum of increasing degrees of vertical coordination¹ between the production and handling activities required to transform a product from its primary form and location to its consumer-ready form in the retail market. The other end of the spectrum can be characterized by the spot market (Sheldon)

or the open market (Barry, Sonka and Lajili) in which exchange decisions are based on price signals alone. Open market exchange may be inefficient where uncertainty, including imperfect and asymmetric information, leads to risk (Blair and Kaserman; Robison and Barry);² where the transmission of input or output specifications increases contracting costs and the costs of searching for alternative trading partners (Blair and Kaserman); or where technological or financial economies in combining a number of activities within the management of a single firm exist (Barry, Sonka and Lajili; Blair and Kaserman; Kilmer). In such cases, vertical coordination is a competitive strategy (Alchian and Demsetz; Streeter, Sonka and Hudson)-redefining the boundaries of the firm to overcome some of the costs associated with open market exchange. Vertical coordination can be achieved through contracting, with varying degrees of specificity in contract details, or by combining the locus of decision-making for various activities under the management of a single firm.

Agricultural economists suggest a number of reasons for the recent increase in vertical coordination in the food supply system. These include increased concentration in the food chain (fewer buyers and sellers from which to choose with attendant transactions costs and risks); an increased need for assurance of supply or demand, particularly for perishable products (Kilmer); changes in technology and asset specificity (Barry, Sonka and Lajili; Kilmer); government regulation of product quality and production and handling practices (Caswell, Roberts and Lin; Hobbs and Kerr; Roberts *et al.*; Streeter, Sonka and Hudson); and increased consumer awareness of, and preference for, particular product attributes as a result of improved information flow (Caswell, Roberts and Lin; Hennessy;

Roberts *et al.*; Streeter, Sonka and Hudson). Recent literature on the subject of pesticide residue levels suggests that growing concerns over pesticide residues may have an impact on vertical coordination through firms' reactions to changes in consumer preferences and in government regulations.

Consumer Preferences and Government Regulations as Incentives for Vertical Coordination

A number of recent studies have revealed increasing consumer concern about pesticide residues in food and "a high level of perceived risk among American consumers about pesticide residues" (Misra, Huang and Ott). Misra, Huang and Ott found that the testing and certifying of produce to be pesticide residue-free and the monitoring of pesticide use were actions strongly preferred by the majority of a sample of Georgia consumers, though most were not willing to pay higher prices for pesticide-free produce. Roberts *et al.* cite Food Marketing Institute surveys that indicate that, "...the majority of consumers were very concerned about food safety," and, "...the average U.S. consumer appears willing...to pay the added costs associated with producing safer foods" (p. 4). Furthermore, population growth, rising incomes (given the likelihood that demand for safe food is income elastic), and the possibility that new scientific knowledge might increase awareness of the possible negative effects of pesticide residues, suggest that the market for safer food will continue to grow (Caswell, Roberts and Lin; Roberts *et al.*).

Consumer concern about food nutritional value, safety and production practices has changed the determinants of food marketing strategies. Previously marketing firms

were charged with influencing consumer preferences for commodities that were homogeneous at the farm level. Today, marketers work to discover consumer preferences for specific product attributes, many of which can only be met by product differentiation at the producer level (Barry, Sonka and Lajili; Streeter, Sonka and Hudson). The transmittal of information about consumer preferences to the producer level is therefore becoming critical to competitiveness as is the creation of incentives for producers to undertake the costs and effort involved in providing safer food (Hennessy; Roberts *et al.*). Equally important is the ability of marketers to convey information about product attributes and to provide consumers with an assurance of food safety. The need to improve the flow of information creates an incentive for vertical coordination, especially where information is asymmetric and buyers perceive a risk of adverse selection (Streeter, Sonka and Hudson; Hennessy).

Streeter, Sonka and Hudson provide examples of ways in which information, production technology and practices, and testing technology have been used to identify consumer preferences, to transmit this information upstream through the marketing channel, and to ensure that product that flows downstream meets attribute specifications. However, they point out that even if improved information flow is made feasible, a profit incentive is required for firms to invest in changing their production or handling practices to meet consumer demand. Hennessy draws on probability theory and the equality between returns and costs that guides firm-level decision-making to show that information asymmetries prohibit the price mechanism from signaling appropriate investment in quality-improving capital. In particular, he considers the case in which processors do not

have information about producers' investments in quality-improving capital, but determine price premiums for high-quality products by testing product samples and by considering the probability of sampling and testing errors in determining average product quality. Hennessy shows that inaccuracy in sampling and testing discourage investment in quality-improving capital by reducing the price premium awarded for high-quality products and creating an externality for firms that do invest. High testing costs will also discourage investment, whether or not there is inaccuracy in testing. Both testing errors and costs create asymmetric information which "motivates vertical integration because a firm that both produces and processes does not need to test to learn about average quality" (Hennessy, p. 1041).

Consumer preferences for nutritious and safe food partly have been informed by government regulations and education efforts. The EPA sets standards for pesticide residue levels in food based on likely intake over a period of time for the consumption of a typical basket of goods. The EPA standards consist primarily of maximum tolerance levels specified by chemical compound and by food product. Residue levels are monitored by testing samples taken from both growers and handlers at various times of the year.

In Florida, this testing is carried out by the Florida Department of Agricultural and Consumer Services' (FDACS) Chemical Residue Laboratory (CRL). CRL agents collect samples from growers and handlers, weighting their collection strategy toward growing seasons and regions that are most prone to high residue accumulations. Both the surface and interior of the product are tested. A test result that shows residues above EPA tolerance levels will result in a particular batch, or lot, of product being withheld from the

market while further tests are conducted. Conclusive findings of above-tolerance residue levels result in the loss of the batch in question, possible fines and frequent monitoring of subsequent output for some time into the future.

Potential costs of food safety risks include financial penalties, the costs of investigation, plant (or farm plot) closings, liability suits, and losses due to decreased demand and product recall (Caswell, Roberts and Lin; Roberts *et al.*). In discussing the incentives for vertical coordination created by the 1990 UK Food Safety Act, Hobbs and Kerr suggest that the transferal of the liability for food safety to all parties in the marketing channel generates both direct and indirect costs to firms. Direct costs may include the administration of new monitoring procedures, the purchase of equipment, the training of employees, and so forth. Indirect costs, which are less transparent and result from imperfections in the market exchange process, may include costs resulting from the duplication of monitoring efforts-firms must both monitor themselves and be monitored by the firms they sell to-increased contracting and search costs and the costs of insuring against legal suits. Indirect costs will be even greater if the downstream firm has to overcome information asymmetries in monitoring its sellers.

Liability for product safety is not allocated as clearly in the US as in the UK (Perloff and Wolf). While much of the responsibility for a failure to ensure food safety may lie with the producer or first-handler, in the U.S. financial liability often falls on firms that are further downstream. This is partly because of the difficulty of tracing a particular unit of product back to its source and partly the result of a legal convention that transfers financial liability to the party most capable of paying (“deep pockets”). Packers and

distributors therefore have an incentive to guard against purchasing low-quality product, and retailers prefer dealing with larger, more well-established handlers that are known for having reliable product sources. Consequently, larger downstream firms have greater incentives to ensure the quality of their purchases or to closely monitor the cultural practices of the producing or handling firms with which they trade through vertical coordination.

Theoretical Model

Product quality is predicated by an overall mix of product attributes of which food safety is a subset. The attributes can be expressed as characteristics (e.g., no pesticide residues) or in terms of services provided (e.g., reduces health risks) (Roberts *et al*). The level of pesticide residues in a food product can therefore be seen as one of a number of attributes that determine product quality. If a product is purchased as an input to a production or transformation process, its attributes render a service to the process, such as adding value to the final product. Variability in the pesticide residue content of an input will introduce uncertainty about input quality with respect to its food safety attributes. Inasmuch as it may reduce output marketability, increase input or output rejection rates, or introduce testing, monitoring, contracting costs, uncertainty over pesticide residue levels may have a negative impact on a firm's utility from profits. Decision-makers will therefore have to account for the impact of input quality risk.³.

The general framework for analyzing firm-level decision-making under risk is based on the Von Neumann and Morgenstern expected utility model. Robison and Barry

show how this model can be applied to a firm that aims to maximize its utility from profits given a trade-off between risk and returns. As is customary, decision-makers will be assumed to be risk-averse, implying a concave (diminishing marginal) utility function.

The model considers a decision-maker participating in an uncertain event with variable profit outcomes that occur with known probability. Robison and Barry show that the expected utility derived from variable profits is equal to the utility derived from the *certainty equivalent*, π_{CE} . The certainty equivalent is the profit from an uncertain event at which the decision-maker would have been indifferent in choosing between the certain and uncertain events. It is related to the expected profit, $E(\pi)$, as

$$(1) \quad \pi_{CE} = E(\pi) - \frac{\lambda}{2} \sigma_{\pi}^2,$$

where λ is a measure of risk aversion and σ_{π}^2 is the variance of profit (Robison and Barry, p. 39-40). The last term on the right-hand side is the risk premium. Given the decision-makers' indifference between profit from a certain event and the certainty equivalent, the optimal choice for a decision-maker faced with uncertainty is the solution to the maximization of utility from the certainty equivalent. Robison and Barry show that, under certain conditions, this is equivalent to maximizing the certainty equivalent (p. 71-75).

Since input quality is a function of the services provided by an input, some quantitative measure of the quantity (or level) of services, x_1 , provided by an input can be used as a proxy for input quality (Robison and Barry, p. 118-121).⁴ Let the production

function for a firm faced with stochastic variation, ε , in input quality (i.e., in the level of services provided by one of its inputs) and a certain quantity of all other inputs, x_2 , be

$$(2) \quad q = f(x_1 + \varepsilon | x_2),$$

where q is the quantity of output produced; $f'_1 > 0$, and $f''_1 < 0$, (f'_1 is the partial derivative of equation (2) with respect to x_1); and $\varepsilon \sim (0, \sigma_\varepsilon^2)$. Furthermore, $\varepsilon > -x_1$ to ensure that the quantity of services is always positive. The firm's profit function, expected profit and variance of profit are given by

$$(3) \quad \pi = pf(x_1 + \varepsilon | x_2) - r_1 x_1 - r_2 x_2,$$

$$(4) \quad E(\pi) = pEf(x_1 + \varepsilon | x_2) - r_1 x_1 - r_2 x_2,$$

$$(5) \quad \sigma_\pi^2 = p^2 \sigma_q^2,$$

respectively (Robison and Barry, p. 118). π is profit; p is the output price; r_1 is the price of x_1 ; and r_2 is the price of x_2 . σ_q^2 is the variance of output and is a function of x_1 . It can be shown that the expression for certainty equivalent maximization is

$$(6) \quad \max \pi_{CE} = pEf(x_1 + \varepsilon | x_2) - r_1 x_1 - r_2 x_2 - \frac{\lambda}{2} p^2 \sigma_q^2,$$

where the last term on the right-hand side represents the risk premium derived by Pratt and λ is a measure of risk aversion (Robison and Barry, p. 34).

The first-order condition for certainty equivalent maximization with respect to x_1 is

$$(7) \quad \frac{\partial \pi_{CE}}{\partial x_1} = p \frac{\partial Ef(x_1 + \varepsilon | x_2)}{\partial x_1} - r_1 - \frac{\lambda}{2} p^2 \frac{\partial \sigma_q^2}{\partial x_1} = 0.$$

Robison and Barry (p. 119) show that, assuming a concave production function, $f(x_1)$, increasing x_1 from x_1 to x_1^* (Figure 1) will decrease the variance of output, σ_q^2 , for a

given variance in x_1 . Since $\frac{\partial \sigma_q^2}{\partial x_1} < 0$, the impact of input quality risk is to reduce the

marginal value product of input quality from r_1 (equation (3)) to $r_1 - \frac{\lambda}{2} p^2 \left| \frac{\partial \sigma_q^2}{\partial x_1} \right|$

(equation (7)). The decrease in output variance that results from an increase in input quality, x_1 , will decrease the variance of profits (equation (5)). This results in a higher certainty equivalent (equation (1)) and, therefore, in a higher expected utility from profits.

A framework similar to that used by Robison and Barry (p. 24-25) to analyze the relationship between profit variability and expected utility can be used to show that a decrease in the variance of input quality can increase expected output for a given expected input quality. Figure 2 depicts a concave production function for which expected output, given a variation in possible input levels, is determined from a convex combination of the outputs generated by each of these possible input levels. As a result, expected output is higher with a smaller variance, $x_1 \pm \varepsilon_2$, in input quality than with a larger variance, $x_1 \pm \varepsilon_1$, in input quality. In other words, $Ef(x_1 \pm \varepsilon_2) > Ef(x_1 \pm \varepsilon_1)$. Equation (4) shows that a higher expected output will increase expected profits. Certainty equivalent (equation (1)) and expected utility from profits will therefore also increase.

The preceding shows that there is a very clear incentive, based on maximizing utility from profits, for a firm facing uncertain input quality to seek to both increase input quality and decrease input quality variability. The discussion in the first and second sections of this article suggests that vertical coordination allows for the control of, and increased information about, input quality that can allow downstream firms to increase the level and reduce the variability of input quality. Given the *inverse* relationship between input quality and pesticide residues, it is expected that vertical integration will result in a lower mean and variance of pesticide residues in food products.

Data and Results

Stevens and Kilmer (1995) assembled data on the pesticide residue content of Florida strawberries and tomatoes sampled from growers and tested by the CRL.⁵ The data comprised residue content, in parts per million (ppm), of specific chemicals, which were then grouped into fungicides and insecticides. Pesticides are divided into insecticides and fungicides to reflect differences in the types of pest problems involved and in pesticide application strategies. Insecticides are more likely to be applied to control specific populations while fungicides are often applied as a preventive measure against climatic variations and imperfect humidity control during storage and packing. The growers from whom these samples were taken were then interviewed to gather information on their socio-economic characteristics and production and handling practices.

The data set included 55 tomato grower observations and 50 observations on strawberry growers. Of the tomato growers, 16 reported that they were not formally affiliated with the packing, distribution or marketing stages and 39 shared common

ownership with one or more of these stages. Of the strawberry growers, 30 were not formally affiliated with the packing, distribution or marketing stages and 20 shared common ownership with the downstream stages. The analysis was conducted using data for non-affiliated and vertically integrated firms only.

Because of a large number of zero pesticide residue levels in the dependent variables, four Tobit models were run and the models were corrected for heteroskedasticity. The independent variables are defined in table (1) and the results of the Tobit models are included in tables (2-5). The vertical integration variable (VI) was negative in all four models which indicates that a vertically integrated grower reduces the pesticide residue levels found in strawberries and tomatoes compared with a non-vertically integrated firm; however, the VI variable was significant in only the tomato insecticide model (Table 5).

The error term from each Tobit model was sorted into a vertically integrated group and a non-vertically integrated group. The variances of the error terms were computed and analyzed for vertically integrated and non-affiliated tomato and strawberry growers (Table 6). Bartlett's test for homogeneity of variances (Bartlett; Gujarati, p. 343-344) was used to determine whether the differences between the variances were statistically significant. The null hypothesis is $H_0: \sigma_1^2 = \sigma_2^2 = \dots = \sigma_k^2 = \sigma^2$, where σ_i^2 are the variances of i independent and normally distributed samples and σ^2 is the population variance. Bartlett's test suggests whether or not the sample variances are estimates of the same population variance. The Chi-square value is given by

$$(8) \quad \chi^2_{calc} = \frac{f \ln s^2 - \sum (f_i \ln s_i^2)}{1 + \frac{1}{3(k-1)} \left[\sum \left(\frac{1}{f_i} \right) - \frac{1}{f} \right]},$$

which is distributed as a Π^2 distribution with $k-1$ degrees of freedom. s_i^2 is the variance of a sample with f_i degrees of freedom drawn from the normally distributed population with variance σ_i^2 ; s^2 is a pooled estimate of the population variance, σ^2 ; and k is the total number of independent, normally distributed samples drawn from the population.

Vertically integrated strawberry growers showed lower residue variances than non-vertically integrated growers (Table 6). Furthermore, they were both statistically significant. This indicates that vertically integrated growers control the application of pesticides more carefully than non-vertically integrated growers. The strawberries coming from vertically integrated growers will be more uniform in the level of pesticide residue present in strawberries.

Vertically integrated tomatoes growers have already been shown to have lower insecticide residue levels than non-vertically integrated growers (Table 5). Furthermore, the variance of insecticide residue levels in tomatoes is lower in vertically integrated firms than non-vertically integrated growers (Table 6); however, the variances are not statistically different. Thus, tomatoes coming from vertically integrated growers will have lower insecticide residues than non-vertically integrated growers, but the uniformity between the two types of growers will not vary.

In contrast, the fungicide residue variance was significantly higher for vertically integrated tomato growers than for non-vertically integrated tomato growers. Fungicide

application is motivated by decision-makers' evaluations of the potential for fungus problems, based on the current and expected future climatic conditions. Tomatoes coming from vertically integrated growers will vary more in the amount of fungicide residue present in the tomato than non-vertically integrated growers. This suggests that uniformity among the tomatoes coming into the packinghouse is not an issue with the packinghouse. Tomatoes are washed once they enter the packinghouse which washes away the fungicide present on the outer surface of the tomato.

Summary, Conclusions and Implications

Increased public concern about pesticide residues in food has placed pressure on agricultural producers and processors to reduce pesticide residues. This pressure impacts firms through the risks and costs of failing to meet government regulatory standards and through increased opportunities for product differentiation on the basis of safer food. Where input quality influences profitability, firms may react to uncertainty about input quality by seeking to increase the mean level and reduce the variance of input quality. In the case of pesticide residues, this implies efforts to reduce the mean level and variance of pesticide residues in inputs. This article analyzes data on pesticide residues and the occurrence of vertical integration from a sample of Florida strawberry and tomato growers. The hypothesis tested is that products sampled from vertically integrated firms will have lower mean levels and variances of pesticide residues.

Vertical integration was associated with significantly less varied fungicide and insecticide residues from Florida strawberry growers. This means that the strawberries coming from vertically integrated strawberry growers is a more uniform quality than that

from non-vertically integrated growers. Furthermore, the tomatoes coming from vertically integrated tomato growers are of higher quality because of lower insecticide residue levels than non-vertically integrated growers. In contrast, vertical integration appears to be significantly associated with more varied fungicide residues. The difference between the impact of vertical integration on the two types of residues may point to the importance of the extent to which residue content can be controlled.

This study represents the first known attempt to quantify the relationship between food safety and vertical coordination in agricultural markets. The results confirm the positive relationship hypothesized in the growing number of qualitative studies in this area, at least for the case of fungicide and insecticide residues in Florida strawberries and the insecticide residues in Florida tomatoes. Some of the limitations of this study suggest important topics for further research. In particular, a similar study using data collected randomly would allow implications to be drawn for a broader population. In addition, information about the weightings assigned by firms to their various product quality objectives would allow the effects of conflicting objectives to be identified. Finally, further evidence of a negative relationship between vertical coordination and pesticide residues in food may suggest important market-based targets for government policies aimed at improving food safety. These may include measures to improve information transfer at all levels of the market through unified grading and labeling standards, improved information technology and more accurate and less expensive testing mechanisms.

Figure 1. Relationship between input service quantity and output variability.

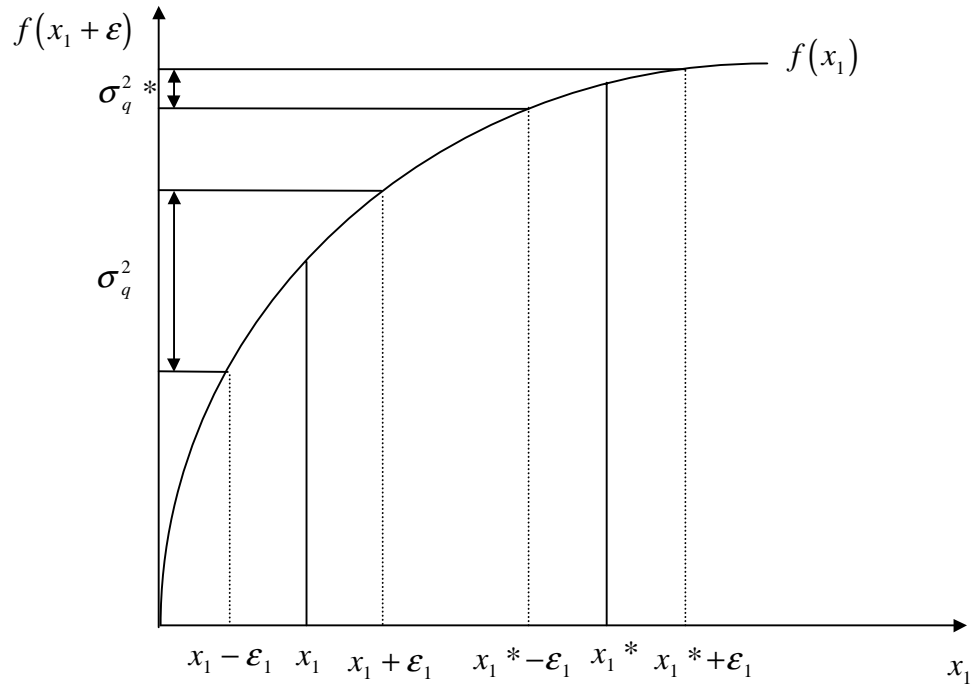


Figure 2. Relationship between input variability and expected output.

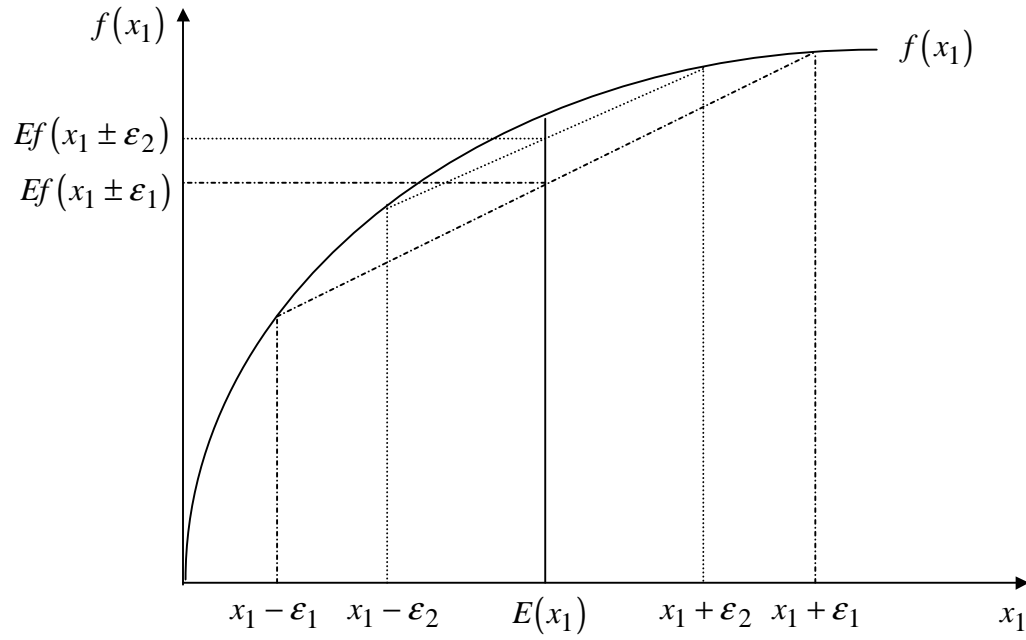


Table 1. Description of Independent Variables used in Tobit Estimations

Variable	Name	Description
Decision Maker's Role	FUNCT	1=owner, 2=partner, 3=manager
Education	EDUC	1=No high school 2=completed high school 3=Vocational training after high school 4=Some college 5=Completed college 6=Graduate school
Experience	EXP	Number of years involved in strawberry (tomato) production.
Certified for Restricted Pesticide Use.	CERT1	0=no, 1=yes
Acres rented	ARENT	Acres
Total acres	ATOT	Acres
Soil Type	SOIL4	0=sand, 1=loam
Soil Type	SOIL6	0=sand, 1=sandy loam
Vertically Integrated	VI	0=no, 1=yes
Harvest Month's Average Temperature	TAVG0	Average degrees
Harvest Month's Rainfall	RF0	Inches
Month Before Harvest Average Temperature	TAVG1	Average degrees
Month Before Harvest Rainfall	RF1	Inches

Table 2. Maximum Likelihood Coefficient Estimates for Fungicide Residues on Strawberries.

Independent Variables	Coefficient ^a	Std. Error	Beta/ Std.Error	Level of Significance	Mean of Variable
CONSTANT	-56.2072	50.32248	-1.117	0.264	
FUNCT	-5.14398	2.008114	-2.562	0.0104	1.26
EDUC	0.34277	0.400426	0.856	0.392	2.76
EXP	-5.56E-02	0.106259	-0.523	0.6007	19.84
CERT1	8.600907	14.5958	0.589	0.5557	0.96
ARENT	-1.21E-02	3.31E-02	-0.366	0.7141	19.38615
ATOT	-6.03E-02	2.61E-02	-2.311	0.0209	38.88654
SOIL4	-9.73605	0.792839	-12.28	0	0.3
SOIL6	-3.42185	2.067149	-1.655	0.0979	0.2
VI	-0.3029	1.426155	-0.212	0.8318	0.4
TAVG0	-0.14559	0.56178	-0.259	0.7955	63.354
RF0	0.577206	0.294277	1.961	0.0498	5.055
TAVG1	1.132394	0.216583	5.228	0	61.388
RF1	-9.64E-02	0.568319	-0.17	0.8653	2.8608
Log-Likelihood Value	-110.3733				
Observations	50				

^a A likelihood ratio test was used to test for heteroskedasticity. Heteroskedasticity was found and corrected, assuming that $\sigma_i^2 = \sigma^2 e^{(\beta z)^2}$.

Table 3. Maximum Likelihood Coefficient Estimates for Insecticide Residues on Strawberries.

Independent Variables	Coefficient ^a	Std. Error	Beta/ Std.Error	Level of Significance	Mean of Variable
CONSTANT	2.142555	62.63743	0.034	0.9727	
FUNCT	-0.28807	0.799145	-0.36	0.7185	1.26
EDUC	1.64E-02	0.309049	0.053	0.9577	2.76
EXP	1.42E-02	9.19E-03	1.547	0.1218	19.84
CERT1	-0.19746	0.486047	-0.406	0.6846	0.96
ARENT	5.01E-03	1.80E-02	0.278	0.781	19.38615
ATOT	-3.14E-03	1.12E-02	-0.281	0.7789	38.88654
SOIL4	-3.55E-02	0.347573	-0.102	0.9187	0.3
SOIL6	0.4846	3.053206	0.159	0.8739	0.2
VI	-0.29922	2.185652	-0.137	0.8911	0.4
TAVG0	-0.21037	1.689799	-0.124	0.9009	63.354
RF0	0.108408	0.428534	0.253	0.8003	5.055
TAVG1	0.182204	0.78271	0.233	0.8159	61.388
RF1	-0.16422	1.732965	-0.095	0.9245	2.8608
Log-Likelihood Value	-20.6285				
Observations	50				

^a A likelihood ratio test was used to test for heteroskedasticity. Heteroskedasticity was found and corrected, assuming that $\sigma_i^2 = \sigma^2 e^{(\beta z)^2}$.

Table 4. Maximum Likelihood Coefficient Estimates for Fungicide Residues on Tomatoes.

Independent Variables	Coefficient ^a	Std. Error	Beta/ Std.Error	Level of Significance	Mean of Variable
CONSTANT	-3.148973486	2.3943204	-1.315	0.1884	
FUNCT	-0.162278969	0.15340278	-1.058	0.2901	2.4363636
EDUC	0.266389933	0.18318215	1.454	0.1459	4.2909091
EXP	7.69E-02	4.97E-02	1.548	0.1217	14.872727
ARENT	-2.55E-03	1.49E-03	-1.714	0.0865	266.18182
ATOT	5.29E-04	3.09E-04	1.712	0.0869	1078.1091
SOIL6	-0.904981714	0.77136609	-1.173	0.2407	0.34545455
VI	-0.100647714	0.51704557	-0.195	0.8457	0.70909091
TAVG0	3.34E-02	1.94E-02	1.719	0.0857	73.976364
RF0	-2.00E-03	6.87E-02	-0.029	0.9768	2.1449091
TAVG1	-1.29E-02	1.90E-02	-0.682	0.4955	73.205455
RF1	-1.20E-02	3.12E-02	-0.386	0.6996	2.2838182
Log-Likelihood Value	17.9160				
Observations	55				

^a A likelihood ratio test was used to test for heteroskedasticity. Heteroskedasticity was found and corrected, assuming that $\sigma_i^2 = \sigma^2 e^{(\beta z)^2}$.

Table5. Maximum Likelihood Coefficient Estimates for Insecticide Residues on Tomatoes.

Independent Variables	Coefficient ^a	Std. Error	Beta/ Std.Error	Level of Significance	Mean of Variable
CONSTANT	1.514795904	1.7163648	0.883	0.3775	
FUNCT	2.96E-02	0.10573168	0.28	0.7796	2.4363636
EDUC	0.122636629	0.1255652	0.977	0.3287	4.2909091
EXP	2.17E-02	2.26E-02	0.96	0.3372	14.872727
ARENT	-1.90E-04	4.62E-04	-0.411	0.6813	266.18182
ATOT	1.09E-04	8.84E-05	1.233	0.2177	1078.1091
SOIL6	-7.83E-02	0.32684683	-0.24	0.8106	0.34545455
VI	-0.408923518	0.12627034	-3.238	0.0012	0.70909091
TAVG0	-2.58E-02	3.31E-02	-0.779	0.4361	73.976364
RF0	3.84E-04	2.78E-02	0.014	0.989	2.1449091
TAVG1	-7.68E-03	1.16E-02	-0.66	0.5095	73.205455
RF1	1.35E-01	4.32E-02	3.123	0.0018	2.2838182
Log-Likelihood Value	23.6744				
Observations	55				

^a A likelihood ratio test was used to test for heteroskedasticity. Heteroskedasticity was found and corrected, assuming that $\sigma_i^2 = \sigma^2 e^{(\beta z)^2}$.

Table 6. A Statistical Comparison of the Variance of the Tobit Residuals Sorted by Vertically Integrated (VI) and Non-Vertically Integrated (NVI) Growers.

		Tomatoes ^a		Strawberries ^a	
		Fungicides	Insecticides	Fungicides	Insecticides
Variances	NVI	0.000	0.015	21.330	0.595
	VI	0.039	0.011	14.949	0.036
Bartlett's test		204.000**	0.000	3.945**	30.675**

^a A double asterisk indicates statistical significance at the 5 percent level based on a one-tail chi-squared test of Bartlett's coefficient for the variances.

Notes

1. Unless otherwise specified, the term vertical coordination will encompass vertical integration.
2. The differences between, and interactions among, the concepts of uncertainty, imperfect information and risk are well delineated by Robison and Barry (Ch. 2) and Philipps (Ch. 1).
3. Certain product attributes may present the firm with competing objectives. For example, reducing pesticide residues may require a reduction in pesticide applications. However, reducing pesticide applications may reduce the producer's ability to control the product's appearance and to reduce perishability, both of which may also be important product attributes. The relative importance of various attributes to profitability will be taken into account when evaluating the results of the analysis.
4. In the case of input quality based on pesticide residues, x_1 might be the residue content in parts per million (ppm) with lower values for x_1 reflecting a higher residue content.
5. CRL collection strategies are biased toward growing regions and seasons that are most prone to high residue accumulation. While the results may not, therefore, be generalized over the entire population, they may be indicative of the responses of firms for which pesticide residue content is a major concern.

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